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Temperature dependence of antiferromagnetic resonance mode in two-dimensional system $Ni_5(TeO_3)_4Br_2$

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Abstract

Antiferromangentic resonance (AFMR) in layered $Ni_5(TeO_3)_4Br_2$ system with a geometrically frustrated Ni^{2+} ($S = 1$) spin arrangement has been investigated. Temperature dependence of the lowest mode resonant field could be described with a simple two sublattice model, considering different magnetic susceptibilities. The AFMR linewidth follows a power law $T^{2.8}$, due to the magnon–magnon scattering processes.

Keywords: Antiferromagnetic resonance; Single-ion anisotropy; Frustration

1. Introduction

Frustration of magnetic order is encountered in systems where all the pair-wise interactions between the magnetic moments cannot be satisfied at the same time. Typical example is given by antiferromagnetically interacting spins in a triangular lattice. Ni^{2+} ($S = 1$) moments in new layered $Ni_5(TeO_3)_4Br_2$ system are arranged in an interesting double triangular topology [1], where frustration might play an important role. We stress, however, that NiO_6 octahedra are strongly distorted, resulting in a large single-ion anisotropy, which would act against frustration and favor magnetic ordering. As a consequence, below $T_N = 29\,K$, the $Ni_5(TeO_3)_4Br_2$ orders antiferromagnetically [1]. Magnetic order can be described with a 10 non-collinear sublattices [2,3]. From neutron diffraction [3], the magnetic moment was determined to be $\sim 2.15\mu_B/Ni^{2+}$, while from the magnetization measurements [4] one would expect $\mu_{eff} = g(S(S+1))^{1/2}\mu_B \sim 3.5\mu_B/Ni^{2+}$.

We investigated the temperature dependence of antiferromagnetic resonance (AFMR) field and linewidth in order to understand the temperature dependence of sublattice magnetizations.

2. Experimental results and discussion

The antiferromagnetic resonance signal measured at $\nu_L = 324\,GHz$ and $\boldsymbol{B} \| a^*$ axis was detected below $T = 15\,K$. With decreasing temperature, the linewidth of the AFMR signal dramatically reduces from $\Delta B = 1.7\,T$ at $15\,K$ to $0.075\,T$ at $1.5\,K$. We also notice a small anomaly at around $5\,K$ (Fig. 1).

Temperature dependence of the AFMR field exhibits even more complex behavior (Fig. 2). With decreasing temperature, the resonance field first increases down to $T = 8\,K$, where it reaches a broad maximum at $B_{res} = 5.33\,T$. On further cooling, the trend reverses and resonance field is reduced to $5.15\,T$ at $T = 1.5\,K$ [3].

The temperature dependence of the resonance signal linewidth (Fig. 1) between 15 and 5 K can be phenomenologically described with a power law $\Delta B \propto T^{\gamma}$, $\gamma \sim 2.8(3)$.

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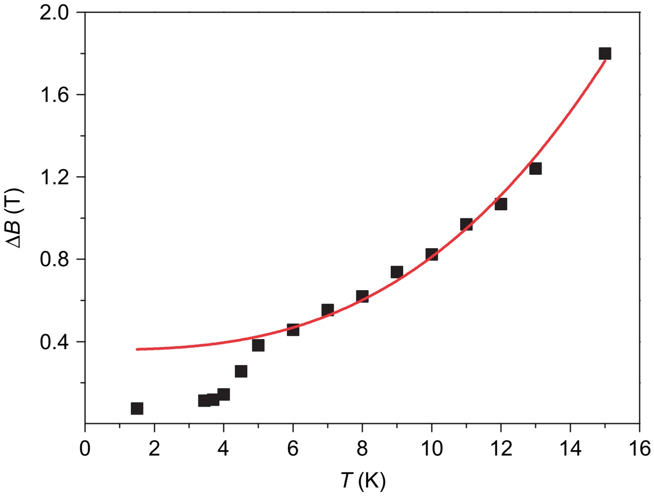

Fig. 1. Temperature dependence of the AFMR linewidth and fit (solid line) to power law $T^{2.8}$.

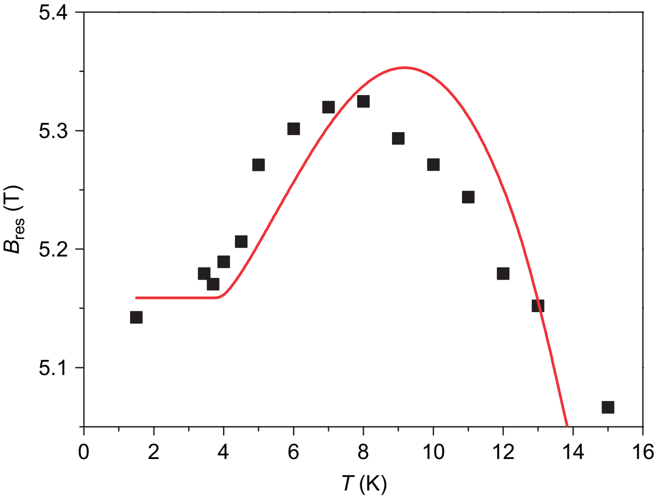

Fig. 2. Temperature dependence of the AFMR field. Solid line presents a fit to the model described in text.

We note at this point that AFMR linewidth is usually determined by four magnon scattering processes leading to T^4 dependence [5,6]. The anomaly at $T = 5$ K as well as the deviation from the T^4 power law thus probably reflect peculiarities in the magnon spectrum in $Ni_5(TeO_3)_4Br_2$.

To account for the temperature dependence of the resonance field let us simplify our system with a two sublattice model. Modifying the equation given in Ref. [7] for our problem, for $\boldsymbol{B} \| a^*$ we find $B_{res} = h\nu/g\mu_B - 2(K_1/\chi_{a^*} + K_2/\chi_b)^{1/2}$, where χ_a and χ_b stand for magnetic susceptibilities parallel to a^* and b crystal axes and K_i are corresponding effective anisotropy constants. Using the magnetic susceptibility data from Ref. [3] and the temperature dependence of the resonance field (Fig. 2) we obtained satisfactory fit with $(2K_1/\chi_{a^*})^{1/2} = 5.1$ T and $(2K_2/\chi_b)^{1/2} = 6.06$ T. In frequency scale, parameters correspond to 141.1 and 170.4 GHz, respectively. These values should be compared to the zero-field gap ~450 GHz and zero-field splitting between the lowest resonant modes ~90 GHz [3,8].

3. Conclusion

We showed that the temperature dependence of the AFMR field in the $Ni_5(TeO_3)_4Br_2$ can be in first approximation described with a two sublattice model. The anomalous increase of the linewidth with increasing temperature is likely to be governed by the magnon–magnon scattering processes.

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